bacillus carrier, but at the time of our investigation was excreting no bacilli or too few to be found by the bacteriological methods employed. Later, on his return, he was excreting bacilli more freely and no difficulty was encountered in isolating them. He then disappeared and we could not observe him further. L. M. was a transient normal carrier infected by the milk or more probably through contact with S. M.

We were in error, therefore, because the carrier first found was a normal carrier, a fact unsuspected at the time. The presence of such a carrier raises interesting possibilities. Had we relied wholly upon the Widal reaction for the selection of fecal specimens and had S. M. given positive fecal results at the time, we would have excluded him and agreed to the resumption of the milk supply. Should L. M. have continued to excrete bacilli, the excretion by normal carrier being not necessarily as transient as it was in his case, we should have left an unsuspected carrier, who might have been the source of infection for subsequent cases.

Although a positive Widal reaction may be absent in chronic carriers, the results indicate that even if a farm helper is found to be excreting typhoid bacilli, any other individual giving a partial or positive Widal reaction should be held under suspicion. At least, fecal examinations should be made over a period of time, as excretion even with chronic carriers is intermittent and negative examinations are not infrequent, and may extend over months or even for a year.

Summary.—The presence on a farm of a normal carrier and a chronic carrier, temporarily fecal negative, is a possible source of error in tracing the source of infection of a milk-borne epidemic of typhoid fever.

VENTILATION AFTER FUMIGATION.

ARTIFICIAL VENTILATION OF SHIPS AFTER FUMIGATION WITH HYDROCYANIC ACID GAS.

By S. B. GRUBBS, Surgeon, United States Public Health Service.

The spread of bubonic plague to all parts of the world in recent years has emphasized the necessity of improving the means used for the destruction of rats on board ships, as it is through these animals that the disease is transmitted. It has been shown that rats are great travelers, and that they may be found in all parts of a vessel, from the costly saloons of the liner to the deepest hold of the freighter,[1] and consequently that no part of a ship should be excepted when fumigation is done.

[1] Grubbs and Holsendorf, Public Health Reports, June 20, 1913.

Sulphur dioxide and hydrocyanic acid gas are the fumigants now most used. Sulphur dioxide has been used for many years to destroy the animal carriers of disease. The objections to this agent are the time required and the possibilities of damage by the sulphur fumes. Including the time for dissipation of the fumes, sulphur fumigation consumes rarely less than 16 and often as much as 24 hours.

Hydrocyanic acid gas quickly destroys animal life, does no damage to inanimate objects, and is of but slightly more expense than sulphur, since it has been shown to be efficient in smaller quantities than prescribed by the present quarantine regulations.[1] It is colorless and practically odorless, but, following the rule now in force of testing with small animals,[2] may be considered fairly safe, especially if a rat is used or other animal sufficiently susceptible to the gas.[3]

The time necessary to ventilate a ship is variable. On an average the hold of a vessel will be clear of HCN gas in from one to two hours after removing the hatches. This time depends upon the depth and size of the hold, area of the hatchway, velocity of the wind, humidity, etc. With little wind and high humidity a deep hold may easily be unsafe for many hours and Faget has observed that 12 per cent of the vessels fumigated by him were not free from gas at the end of three hours.[5] It is important that both the quarantine officers and the steamship agents should know in advance when persons may safely return on board. By employing a system of artificial ventilation we secure independence of weather conditions, a saving of time will be effected, and once fumigation has begun the exact time at which the working of cargo may be resumed can be determined.

Acting under bureau instructions an investigation was undertaken at the Boston quarantine station to find, if possible, an efficient means of removing cyanide gas from ships' holds after fumigation so that the uncertainties and delays of natural ventilation could be replaced by a reliable and practicable system.

The plan of pumping the gas from an outside generator into the hold and then aspirating it through the same pipes was first considered. This method, according to Heiser,[4] is used for house fumigation in India. On account of the difficulty in handling a large rubber hose the application of this method was not attempted; neither was the plan to force in the gas and, after the necessary exposure, to replace the gas by fresh air pumped through the same hose. Studies made on both these principles indicated that they were impracticable for application to ship fumigation.

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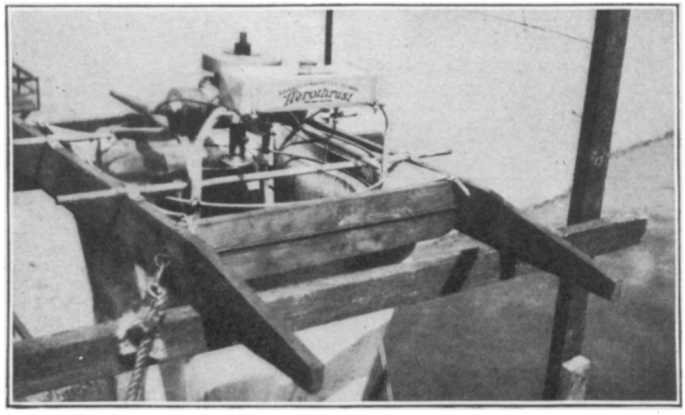
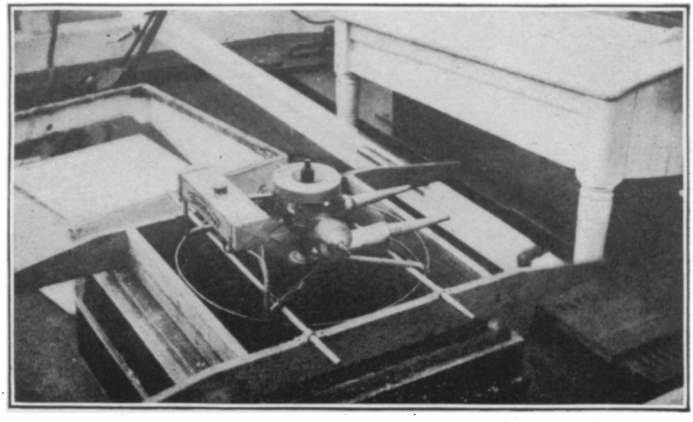
[1] Creel, Faget, and Wrightson, Public Health Reports, Dec. 3, 1915.
[2] Bureau circular letter of Nov. 4, 1916.
[3] Grubbs, Public Health Reports, Apr. 20, 1917.
[4] Personal communication.

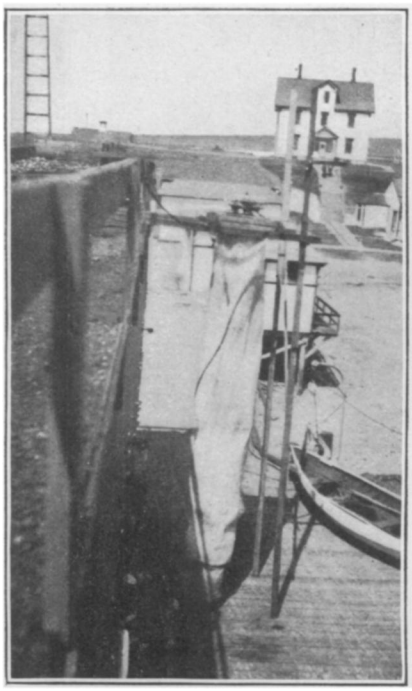
CARRYING THE FAN. THIS MAY BE DONE WITH MACHINE RUNNING.



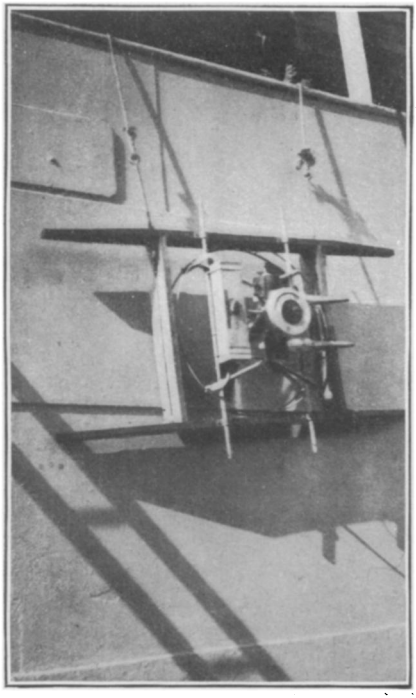
SHOWING DETAILS AND SIMPLE METHOD OF ATTACHING MUSLIN CHUTE.



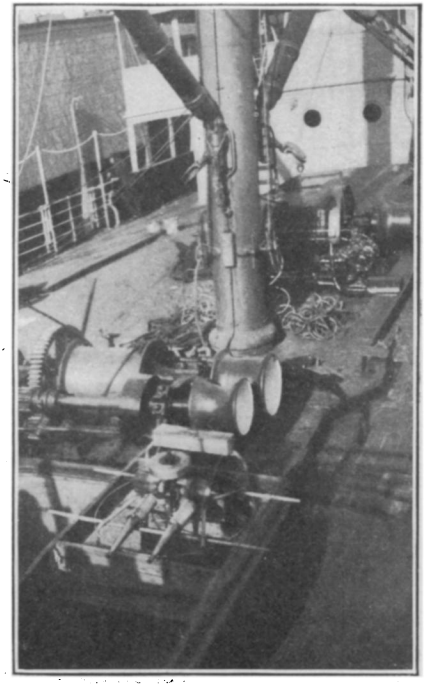
MACHINE PLACED OVER SMALL HATCH IN AFTER PART OF SCHOONER—AIR FORCED IN HERE.



MACHINE WITH MUSLIN CHUTE IN OPERATION SET UP AT STATION FOR TESTING; CHUTE HAS BEEN DOUBLED BACK AT BOTTOM TO CLEAR.



HOISTING ABOARD SHIP. GASOLINE TANK SHOULD BE LESS THAN HALF FULL.



HORIZONTAL FAN OPERATING IN CORNER OF HATCH WITHOUT CHUTE.

Our first experiments were with two electric fans, one a 15-inch ventilating fan propelling 1,500 cubic feet per minute, and the other a blower propelling 500 cubic feet per minute, which were placed in various parts of the holds and operated by the dynamo of the quarantine steamer. Small as they were, these fans shortened the time in which both cyanide and SO_2 fumes could be cleared from compartments, as was shown by using the fans in one hold only of a ship being fumigated. These electric blowers possess little power and the wires are troublesome to handle, consequently they have been abandoned in favor of a gasoline driven air propeller designed to propel boats and sleds. This is a two-cylinder, two-cycle, air-cooled, 3-horsepower gasoline engine, driving a two-blade propeller, 32 inches in diameter, at about 1,600 revolutions per minute. According to measurements made at this station it delivers about 22,700 cubic feet of air per minute. This fan has been tried within the holds, where it served the double purpose of circulating the gas and increasing its penetration, but as it must be operated in a vertical position it was most effectively used for ventilation when attached to the hatch combing, the air being introduced into the hold through a muslin shute 28 inches in diameter. Two shutes were tried, one 20 feet and one 30 feet in length. The shorter one delivered 8,340 cubic feet of air per minute at the outlet. It will be seen that this machine will in 10 minutes deliver into the bottom of the hold an amount of air equal to the aerial content of the average ship's hold, but it has been found that gas is rarely expelled in this short time sufficiently to make the hold safe for persons entering.

The original vertical machine has at our suggestion been changed so that it will operate in a horizontal position, thus driving the air directly downward. Mounted on a wooden frame the horizontal machine weighs less than 100 pounds and may be easily hoisted aboard a vessel. When operated it is placed across the corner of an open hatchway and may be carried from one place to another without stopping the motor. Furthermore, it may be used with or without a shute. In holds of less than 30 feet depth it is probably as efficient without as with a shute, but as this latter can be easily attached by means of four snap hooks it may be advisable to use it when the hatchways are small and the holds deep. Anemometer readings at the bottom of an 18-foot shute gave approximately 8,500 cubic feet per minute and practically the same reading was obtained when the anemometer was held the same distance beneath the machine without the shute.

The following experiment will suffice to show that there should be no attempt to substitute artificial for natural ventilation, but only to supplement nature especially when conditions are not favorable. After fumigation of a hold two hatch covers at opposite corners were removed, the remaining covers being left in place. The machine

with shute was operated at one opening, the other being left open for the escape of gas. Rats were lowered at intervals up to 45 minutes, but all were dead when withdrawn after exposure for 5 minutes. In this interval fresh air to the amount of over four times the cubic capacity of the hold had been delivered at the bottom of the hold, and yet the cyanide persisted in dangerous proportions. Ten minutes after the removal of all the hatch coverings rats lowered into the hold were not affected.

In our experience, a hold has always been safe after most of the hatches have been removed and the aerothrust operated 30 minutes. With two machines, one used aft and the other forward, it is then always possible to have a four-hold vessel ready for release in one and one-half hours or a six-hold vessel ready in two hours after removal of the hatches. Naturally if the holds blown out first require 30 minutes the next one will need less time, as it has been ventilating naturally for a half hour. Since we know that in the foggy weather so common in Boston this gas will remain in the holds for from three to eight hours unless removed by mechanical means, this advantage is evident.

All vessels fumigated at Boston now have their entire superstructure treated with hydrocyanic acid gas. Usually this is ventilated easily without any artificial means, but occasionally, owing either to the structure of the vessel or to weather conditions, considerable delay results unless a fan is used. Large ventilators, when available, are made use of by removing the top and placing the horizontal machine over the opening. The large volume of air thus introduced promptly removes the gas in any kind of weather. In the superstructure and in certain other places the machine which operates vertically and drives the air horizontally is of great service. By directing the air current against the open door of a ship's cabin it acts as a strong wind. Frequently the forecastle or store room when below deck and reached by a companion way is difficult to clear of gas. The blast from the machine if directed down the companion way will do more in a few minutes, frequently, than natural ventilation will do in several hours.

Even more time may be saved by the machine when sulphur dioxide is the fumigant. As it is not probable that a man will enter a hold full of sulphur fumes it is not necessary for the quarantine officer to safeguard sulphur fumigation, but the ship loses rarely less than 6 and frequently as much as 12 hours waiting until it is possible for men to work below deck. This is also especially true on humid calm days. An example may be cited. The steamship *Memphian* was fumigated April 12, 1917, HCN being used for superstructure and sulphur (2 pounds for 12 hours' exposure) in the holds. The latter were opened at 3 a. m. April 13, a foggy day with little

wind. At 9 a. m. the agents telephoned to the station that the sulphur vapors were apparently as thick in the holds as ever, that they had planned to begin loading at 8 a. m., and consequently desired assistance. A man with the aerothrust fan was sent to the ship and in three hours the vessel was clear of fumes. Had the fan been used as soon as the holds were opened loading would have been possible at 8 o'clock as planned. On the other hand if the machine from the station had not been available, loading would undoubtedly have been delayed until the following morning, entailing on the owners a loss of several hundred dollars.

Several times it has been demonstrated that a hold full of sulphur fumes could be cleared in 30 to 40 minutes when other holds, not blown out, were after the same interval apparently as full of the gas as when first opened. On a warm dry day with a good breeze, artificial ventilation is of doubtful advantage after either cyanide or sulphur fumigation, but if any of these conditions are lacking artificial ventilation will save time for all hands. At Boston quarantine the machine is used as a routine after cyanide fumigation regardless of weather conditions, and our experience allows us to recommend the same procedure for other stations. In addition, it is believed that each steamship company whose vessels require fumigation should have at least one horizontal machine for use after sulphur fumigation, as it will save time for their vessels and pay for itself many times over.

Conclusions.

Quarantine stations at which HCN fumigation is practiced should be equipped with mechanical means for artificial ventilation.

The gasoline driven fan as adapted for this use is satisfactory for the prompt ventilation of compartments of vessels after fumigation.

For the expeditious handling of large vessels three machines are recommended, two of the horizontal pattern (downward thrust) and one of the vertical pattern (horizontal thrust).

THE LIGHTING OF INDUSTRIAL ESTABLISHMENTS.

THE NEED FOR SUPERVISION, WITH A SUGGESTED SYSTEM OF MAINTENANCE RATING FOR ARTIFICIAL LIGHT EQUIPMENT.

By DAVIS H. TUCK, Assistant Physicist, United States Public Health Service.

The importance of an adequate, hygienic, and well-distributed system of artificial illumination in industrial establishments is well understood. After such systems have been installed, however, the part played in the upkeep of the illuminating system in maintaining its efficiency at the original level is often slighted. The lack of proper maintenance may reduce the amount of available light by as